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British Columbia | Ministry of Environment

Water

Long-Term Trends in Groundwater Levels in B.C. Methods

Observation well groundwater level time-series data were downloaded from the B.C. Ministry of Environment Groundwater Observation Well Network web application: http: //www.env.gov.bc.ca/wsd/data_searches/obswell/map/obsWells.html. Well metadata, such as location, depth, and aquifer type were obtained from the Ground Water Wells (Spatial View) dataset available from DataBC: http://www.data.gov.bc.ca/dbc/ catalogue/detail.page?config=dbc&P110=recorduid:173681. All data preparation and analysis was performed using the statistical software R (R Core Team 2013).

Trend analysis was conducted using monthly groundwater levels from each groundwater observation well that had more than ten years of data, fewer than 25% of monthly observations missing, and was active as of Jauary 1, 2004. This resulted in 118 wells with suitable records for analysis. For each month that had more than one observation, the median was taken. Missing values were interpolated by first fitting a 12-period (i.e., monthly) basic structural time series model (BSM) to the data (Harvey 1990). Fixed- interval smoothing (Durbin and Koopman 2001) was then applied to the fitted model to generate predicted values for the entire time series; the predicted values were substituted into the orignal time series where there were missing data. This resulted in a full monthly time series for each well, with one observation per month. After the time series were constructed, each was inspected for consecutive missing (interpolated) values near the beginning or the end of the time series, due to the strong influence of these regions on trend analysis. If there were more than four consecutive missing values in the first or last 10% of the time series, the time series was truncated to remove the missing values. Finally, the mean annual groundwater level was calculated for each well, and trend analysis was performed using the annual values.

Each groundwater-level time series was analyzed for trend using Trend-Free Pre- Whitening to remove lag-1 autocorrelation, which can artificially increase the probability of detecting a significant trend (Yue et al. 2002). In this method, the slope of each time series is estimated using the Theil-Sen approach (Sen 1968). If the estimated slope is different from zero, then the data are detrended by the slope and the AR(1) 1s calculated for the detrended time series. The residuals and the trend are combined and then tested for significance using the Mann-Kendall trend test. These methods were implemented using the R package 'zyp' (Bronaugh and Werner 2013).

Time series were not corrected for precipitation or any other climatic or hydrologic process. As such no causation for trends are implied.

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Wells were classified as exhibiting a 'large rate of decline', 'moderate rate of decline', 'stable', or 'increasing' trends, based on the magnitude and significance of the calculated trend. If the slope was significantly different from zero ($P < 0.05$) and declined at more than ten cm per year, the well was considered to have a large rate of decline. If the slope was significant and declining at a rate between three and ten cm peryear, it was classified as having a moderate rate of decline. If the slope was significant and increasing at greater than 3 cm per year, it was classified as increasing. All other wells were classified as stable.

References

Bronaugh, D. and A. Werner. 2013. *zyp: Zhang + Yue-Pilon trends package*. R package version 0.10-1. URL: http://CRAN.R-project.org/package=zyp.

Durbin, J. and S. J. Koopman. 2001. *Time series analysis by state space methods*. 2nd ed. Oxford University Press, 253.

Harvey, A. C. 1990. *Forecasting, structural time series models and the Kalman filter*. Cambridge university press.

R Core Team. 2013. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Vienna, Austria. URL: http://www.R-project.org/.

Sen, P. K. 1968. Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association 63 (324): 1379–1389.

Yue, S., P. Pilon, B. Phinney, and G. Cavadias. 2002. The influence of autocorrelation on the ability to detect trend in hydrological series. Hydrological Processes 16 (9): 1807–1829. DOI: 10.1002/hyp.1095. URL: http://dx.doi.org/10.1002/hyp.1095.

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